

## **Chapter 10 – INDICATORS OF THE INPUT, ACCUMULATION AND IMPACT OF MERCURY ON NJ ENVIRONMENT**

### **A. Introduction**

Environmental indicators are direct or indirect measures of environmental quality that are used to assess the status and trends of environmental conditions (NJDEP 1998a). Indicators provide a cost-effective, repeatable, and socially relevant way for tracking pollutants and the risk associated with exposure. The ultimate human and ecological impact of mercury on NJ's environment, while significant and widespread, tends to occur through relatively subtle and difficult to quantify effects on health, performance, and ecological status. Furthermore, the health and ecological endpoints associated with mercury exposure (e.g., neurologic developmental deficits, decreased reproductive success, eggshell thinning) are also associated with other environmental contaminants (e.g., PCBs). It is therefore difficult to design indicators which directly measure these ultimate impacts. Indicators which are somewhat "upstream" of ultimate impacts, but which are, however, predictive of those impacts are therefore, more useful and more appropriate for evaluating and refining the effect of regulatory and advisory efforts. These "upstream" indicators take the form of measures of mercury environmental flux and exposure.

The Task Force considered a variety of indicators which are predictive of the potential for mercury impacts on health and the environment, and which can document trends in those potentials. These are presented below.

### **B. Air Deposition of Mercury**

The NJ Air Deposition Network has begun collecting data on atmospheric mercury deposition in representative parts of the state. Air deposition is an important contribution to mercury levels in aquatic systems. The network has been designed to collect data in a repeatable manner, which can readily be compared across years. Statistical analysis of mercury deposition data generated by the network should be able to elucidate trends in mercury deposition in various parts of NJ. Such trends can be followed statewide and in various regions of the state to determine whether and to what extent atmospheric mercury deposition decreases from various regional sources and overall. Such decreases can then provide a basis for investigating whether indicators of mercury entry and uptake in aquatic systems are also decreasing in response to decreases in atmospheric source contributions.

### **C. Mercury Concentration in Surface Water**

Mercury concentration in surface water is likely to be an important factor in the entry of mercury into aquatic food chains. Because of the large biomagnification of mercury from water to top level aquatic predators, however, small changes in mercury concentration in surface water can lead to large changes in mercury concentrations in fish. The NJDEP's Ambient Stream Monitoring Network currently monitors mercury in surface water at regular stream sampling locations. The detection limit for mercury in those analyses is 0.1 µg/l. In nearly all locations, mercury concentration was below the level of detection. Thus, data from the Ambient Stream Monitoring Network is a useful indicator of significantly elevated mercury in surface water. However, given the magnitude of this detection limit relative to the background levels of mercury in NJ surface waters, such data does not currently provide the



basis for a useful indicator of trends in mercury entry and/or mobilization in surface water and availability to aquatic biota. Improved analytical methods are required. Such an indicator would be extremely useful and would permit the linkage of indicators from currently generated atmospheric deposition data and anticipated indicator data on mercury in aquatic systems.

As discussed previously, the USEPA has recently implemented a new surface water criterion for methylmercury based on not exceeding 0.3 ppm methylmercury in top trophic level fish. The translation of this concentration into a corresponding surface water concentration for either total mercury or methylmercury will likely require implementation of sampling and analytical methods with much lower detection limits than that currently employed by the Ambient Stream Monitoring Network. A fish-sampling program is needed to identify waters that exceed the criterion. Data generated in conjunction with the USEPA Surface Water Criterion should be useful in establishing and following trends in a mercury concentration in surface water indicator.

#### **D. Mercury Uptake in the Aquatic Food Chain**

Mercury enters the aquatic food chain at the lowest trophic level, starting with the methylation of inorganic mercury by bacteria. Due to the large biomagnification of mercury through the food chain to the top-level predators, changes in mercury at any level in the food chain are predictive of changes throughout the chain. Thus, in theory, an indicator of mercury uptake into the aquatic food chain could be based on measurement of mercury concentration in any easily and reproducibly sampled biota. In practice, however, because of this large biomagnification, small changes in mercury concentration at a low trophic level will result in large changes at the top levels. Furthermore, the absolute concentration of mercury at lower trophic levels will be quite small even when levels at upper trophic levels are highly elevated. This makes the development of an indicator based on measurement of mercury in low trophic level biota (e.g., phytoplankton) difficult. An alternative is to develop an indicator based on mercury in upper trophic level biota, which is responsive to short-term changes in mercury uptake. One-year old (young-of-year) fish appear to provide such an indicator (Wiener et al. 1990). While the factors mediating availability and uptake of mercury into the aquatic food chain (e.g., pH, organic carbon content, age of waterbody, etc.) may vary significantly among waterbodies, reproducible sampling of such fish over time within individual waterbodies may provide a reliable basis for the evaluation of trends in mercury uptake into individual aquatic food chains. Viewed in the aggregate, trends in mercury concentration in young-of-year fish for various regions of NJ and statewide, may provide valuable information on how changes in environmental emissions and atmospheric deposition affect aquatic biota.

Trends in mercury levels in NJ fish which are commonly caught and consumed provides the most direct indicator of potential exposure to human and ecological consumers. It is therefore critical that monitoring of this indicator should be carried out on a continuing basis.

Frog tadpoles offer the potential of an indicator species because they are widespread, often abundant, readily studied in the laboratory, and have behaviors that can be quantified. However, simple analysis of whole organisms, would include mercury and other contaminants in the gut, and therefore a period of 48 hours in uncontaminated water is suggested for depuration prior to analysis (Burger and Snodgrass 1998).



## **E. Mercury Levels in Human Tissue**

Mercury, particularly mercury from fish consumption, accumulates in human hair and blood. Sampling of hair and blood in the NJ pregnant population (Stern et al. 2001) as well in other populations elsewhere (USEPA 1997b) have been used to provide a “snapshot” of methylmercury exposure in the population. The design and implementation of a statistically valid and reproducible strategy for sampling mercury levels in hair and/or blood in NJ on a periodic basis could yield estimates of population-based exposure which are comparable from one round of sampling to another. Statistical comparison of these estimates could provide a valid indicator of methylmercury exposure in the NJ population (or in specific subsets of the population such as pregnant women, newborns, adults, etc.). Over time, comparison of multiple rounds of such indicator data would demonstrate trends in methylmercury exposure in the NJ population. Linkage of such trends to trends in mercury levels in commercial fish and/or trends in mercury levels in NJ-specific fish could be investigated.

## **F. Mercury in Indicator Species**

Fish-eating birds such as gulls, terns, herons, and raptors are highly visible and represent top trophic level predators of aquatic and terrestrial ecosystems. Their populations can be monitored, but fluctuations from year to year may obscure long-term trends (Burger et al. 1994). Dramatic population declines of Bald Eagles, Osprey, and Peregrine Falcons, as occurred in the 1940s to 1960's due to DDT, indicated serious contamination (Peakall and Lovett 1972) and were valuable warnings of the widespread impact of persistent pesticides. Many other less conspicuous species were also affected.

Direct measurement of contaminant levels in moribund or dead individuals, may provide information regarding toxicity to the individuals, but is unsuitable as an *indicator* of contaminant burdens. Routine measurement of contaminant levels in unhatched eggs of eagles, ospreys, falcons, hawks, gulls, terns, and herons can provide useful information both on the exposure of the adult birds and on possible impact on hatchability and survival. The data may identify spatial patterns of contamination (Gochfeld 1997) as well as temporal trends (Burger 1993). Eggshell thinning is partly reflective of mercury, but is a more sensitive indicator of organochlorine contamination. Similarly, monitoring of heavy metal levels in feathers of raptors and waterbirds allows documentation of spatial and temporal trends without sacrificing the adult birds---an important consideration particularly for threatened and endangered species (Burger 1993).

Monitoring of reproductive success (nesting attempts, egg laying, hatchability and juvenile survival to fledging, as well as subsequent recruitment of adults to the breeding population) can allow these variables to be used as indicators of environmental quality, but are not specific enough for the monitoring of mercury contamination. However, determining contaminant loads may be important in recovery programs for threatened or endangered species.

In the southern states where humans eat raccoons, this species has proven valuable as a bioindicator for mercury and radionuclides (Gaines et al. 2000). The raccoon offers the advantage of being widespread, conspicuous, and familiar, as well as consuming a wide variety of foods. Although raccoon consumption is not popular in NJ, this widespread animal could also be used as an indicator for ecological impacts.

## **G. New Technologies for Analysis**



The measurement of mercury in environmental media and plant, animal, and human tissues has traditionally been performed by a digestion/extraction procedure followed by cold vapor atomic absorption. A variety of techniques, usually involving gas chromatography, can be used for speciation of organizing mercury (determination of the different mercury species). Detection levels in the ppb range are readily achieved. New techniques have included ultra-clean, mercury free laboratories, and improved detectors, which drive detection levels to the ppt range, although few laboratories have yet acquired these capabilities. These techniques are essential for accurately measuring background levels of mercury in air, water, and lower trophic level biota. Non-destructive analytic techniques are desirable where other studies (molecular, cellular, biochemical) are to be performed on tissues with known mercury concentration. Likewise, techniques that allow the localization of intracellular distribution of mercury exist.

New techniques can also focus on increasing the concentration of mercury in a solution. For example, the use of regenerated cellulose membranes (Babiarz et al. 2000) to concentrate very low levels of methylmercury, are facilitating the determination of mercury in ambient water, reducing detection levels to the sub-nanograms/gram level.

## **H. Summary and Conclusions: Indicators of the Input, Accumulation and Impact of Mercury on NJ Environment**

Indicators provide a critical tool for assessing environmental quality and for evaluating trends in environmental quality especially in conditions of environmental change, such as those which are anticipated to result from reductions in mercury emissions in NJ and the nation. NJ already has in place an elaborate indicator program under its National Environmental Performance Partnerships and Strategic Planning processes.

## **I. Recommendations**

**Address critical information gaps concerning the quantities and chemical species of mercury emissions and releases, the fate and transport of mercury in the environment and the exposure pathways. To accomplish this, NJ should:**

- **upgrade procedures used in all monitoring programs to include state-of-the-art analytical methods to provide lower detection limits for mercury and mercury speciation. (From Recommendation M.1. in Volume 1).**

Programmatic and analytical investments should be made by the NJDEP to permit the establishment and implementation of indicators of mercury in surface water, mercury in aquatic biota (e.g., young-of-year fish), mercury in human tissue (i.e., hair and blood), and mercury in the eggs or feathers of piscivorous birds nesting in NJ. Such indicators are critical tools for evaluating the status and temporal trends of the impact of mercury on NJ's environment. NJ should invest in state-of-the-art analytic technology.

**Develop improved environmental indicators of the impact of mercury on NJ's environment. (From Recommendation "O" in Volume 1).**

- **Expand and maintain a statewide ground water monitoring, program for mercury,**
- **Develop and apply indicators of trends of mercury in environmental media, including air deposition, mercury concentrations in surface water, mercury entry into aquatic food chains, mercury levels in fish tissue, mercury levels in human tissue in the NJ population and mercury levels in feathers of piscivorous birds nesting in NJ.**



Research should be continued to evaluate existing environmental indicators of the impact of mercury on NJ's environment. In addition, additional research should be initiated to permit the development and application of those indicators such as mercury uptake in aquatic food chains which can provide an extremely useful basis for assessing short-term trends in mercury levels and impacts as a means of evaluating the success of mercury reduction efforts.